Some Studies on
Sea Water Ageing Of E-Glass/Epoxy Resin Composite with Different Fiber Orientation

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Under guidance of

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CERTIFICATE

This is to certify that the project entitled, "SOME STUDIES ON SEA WATER AGEING OF E GLASS/ EPOXY RESIN COMPOSITE WITH DIFFERENT FIBER ORIENTATION" submitted by Mr. MANOJ KUMAR PRADHAN in partial fulfillment of requirements for the award of Bachelor of Technology Degree in Metallurgical and Materials Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the project has not been submitted to any other University/ Institute for the reward of any Degree or Diploma.

Date

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Abstract

This project deals with the studies done on sea water ageing of E glass/epoxy resin composite having different fiber orientation. In this project we are trying to find the effects caused by the sea water treatment on composite's mechanical properties and change in properties due to different fiber orientation in composites. Here first of all we prepare the composites by usual hand lay up process taking woven fiber and epoxy resin along with a hardener as raw materials. The composite were made of several glass layers in order to acquire required thickness of ASTM standard. These were then cut into specific dimensions (according to ASTM standard) for samples to be tested for three point bend test in INSTRON. These samples were first heated at 50 degree Celsius in order to stabilize their weight. These were then rolled in aluminum foil in order to have minimum moisture absorption from atmosphere. The samples were then dipped in sea water kept at 60 degree Celsius for an increasing time period of 10 hours and upto 80 hours. After that the samples were taken out and their weight was taken in order to know the amount of water absorbed by the samples. The samples were then tested for 3 point bend test and fracture analysis was done by using SEM. The results of the weighing of the samples shows that water content goes on increasing upto some time of exposure to sea water after that the sea water content becomes constant. Moreover the sea water content does not depend on the fiber orientation. The results of the 3 point bend test shows that the ILSS value of the composites goes on decreasing as the time of exposure to sea water goes on increasing. Moreover as the fiber orientation is changed from 0 to 45 degree the ILSS value goes on decreasing for constant time of exposure. These results show that the sea water when gets absorbed does debonding between the matrix and fiber and then it starts doing the delamination process. If the time of exposure is more then sea water also weakens the fiber thereby causing breakage of fibers. This happens due to various salt ions present in the sea water. The hydroxyl ion which is present in sea water enters the fibers and replaces the originally present sodium ions thereby producing strains due to misfit. So we can conclude that sea water produces a very detrimental effect on composites along with the directionality.

CONTENTS

CHAPTER 1. INTRODUCTION 1

CHAPTER 2. SCOPE OF INVESTIGATION 4
2.1 WORKS DONE BY E.P. GELLERT AND D.M. TURLEY 8
2.2 WORKS DONE BY G. ZAFFARONI & C. CAPPELLETTI 9
2.3 WORKS DONE BY B. C. RAY 10

CHAPTER 3. LITERATURE SURVEY 11

CHAPTER 4. EXPERIMENTAL PROCEDURE 17

CHAPTER 5. RESULTS 19

CHAPTER 6. CONCLUSION 31

CHAPTER 7. REFERENCES 33

LIST OF FIGURES

1. FIGURE 5.1 24

2. FIGURE 5.2 25

3. FIGURE 5.3 27

4. FIGURE 5.4 29
5. FIGURE 5.5 29

6. FIGURE 5.6 30

7. FIGURE 5.7 30

LIST OF TABLES

1. TABLE 5.1 20
2. TABLE 5.2 21
3. TABLE 5.3 21
4. TABLE 5.4 22
5. TABLE 5.5 22
6. TABLE 5.6 23
7. TABLE 5.7 23
8. TABLE 5.8 24
9. TABLE 5.9 26

CHAPTER 1

INTRODUCTION

INTRODUCTION

For over 50 years, fiber-reinforced plastic (FRP) materials have proven to be very successful in structural applications. They are widely used in the aerospace, automotive and marine industries.

The term composite could mean almost anything if taken at face value, since all materials are composed of dissimilar subunits if examined at close enough detail. But in modern materials engineering, the term usually refers to a \matrix" material that is reinforced with fibers. For instance, the term FRP (for Fiber Reinforced Plastic) usually indicates a thermosetting polyester matrix containing glass fibers, and this particular composite has the lion's share of today's commercial market. Many composites used today are at the leading edge of materials technology, with performance and costs appropriate to ultra demanding applications such as spacecraft.

The fibers used in modern composites have strengths and stiffness far above those of traditional bulk materials. The high strengths of the glass fibers are due to processing that avoids the internal or surface flaws which normally weaken glass, and the strength and stiffness of the polymeric aramid fiber is a consequence of the nearly perfect alignment of the molecular chains with the fibers. The fibers may be oriented randomly within the material, but it is also possible to arrange for them to be oriented preferentially in the direction expected to have the highest stresses. Such a material is said to be anisotropic (different properties in different directions), and control of the anisotropy is an important means of optimizing the material for specific applications.

The effect of temperature on moisture diffusion and environmental ageing is a complex phenomenon and not very well established. Moisture absorption at high temperatures may induce irreversible damage to polymers and their composites, such as chemical degradation, cracking and interfacial debonding. The use of GRP composites in critical marine components has usually been accompanied by conservative design safety factors because of limited durability data. Sea water ageing still remains an uncertain factor.

A change in the failure mechanism with increasing temperature can be seen. At room

temperature failure is characterized by matrix cracking and good matrix-fiber adhesion. At 120°C matrix cracking becomes more pronounced and the beginning of fiber pullout can be seen as the glass transition is approached. The modulus is nearly constant for 30 to 100, except for a slight drop at 120°C. This decrease is due to the beginning of fiber pullout failure and increased matrix cracking. As the testing temperature approaches the glass transition temperature, the response of the composite becomes increasingly matrix dominated. This behavior is expected for this composite system, as the flexural modulus decreases with increasing temperature. The mechanism is believed to involve hydroxyl or hydrogen ion penetration into the fibres and these ions progressively replace the sodium ions originally present. The misfit strain due to the replacement of ions may introduce cracks into the fibre surfaces. The aqueous solutions may hydrolyse the siloxane groups of the glass and accelerate flaw growth

This project deals with effect of sea water treatment on E-glass fiber composite as there is not much data known so far in this field. It will provide information about how the ageing of fiber takes place in sea water and then subjected to change in temperature. Since the parts of ship which are made of composite remain in sea for a very long period so here to make such kind of stringent condition the temperature of composite is changed from +60 to -60 degree Celsius and the effect of ageing is studied on fibers having different orientation. This project creates an interest in it because there will be a change in mechanical properties of composite due to temperature and sea water degradation. This degradation causes delamination of fibers which results in change of properties.

CHAPTER 2

SCOPE OF INVESTIGATION

Scope of investigation

The scope of investigation of our project is based on three points:-

- Sea water ageing of composites.
- Directionality in composites.
- Change of temperature on composites.

Sea water ageing: - When composites are immersed in sea water for long time degrading occurs in it. This is due to hydroxyl or hydrogen ion penetration into the fibers and these ions progressively replace the sodium ions originally present. The misfit strain due to the replacement of ions may introduce cracks into the fiber surfaces. The aqueous solutions may hydrolyze the siloxane groups of the glass and accelerate flaw growth. Failure may occur in the interfacial region due to chemical reactions or to plasticisation when water penetrates the interfaces. Moreover the various ions of salts present in sea water (e.g. NaCl, $MgCl_2$) tend to break the bond between carbon and hydrogen present in the epoxy resin and try to get attached to carbon. This also causes strain in matrix due to size change of the atom. Moisture absorption also leads to swelling in matrix. Since swelling of composite lamina is restrained in fiber direction significant residual stresses are induced in multi-directional laminate by moisture absorption. The presence of moisture results in diminution of mechanical properties at elevated temperatures and fatigue life also tend to reduce by moisture absorption (Fig. on page 26).

Directionality in composites: - A unidirectional array of fibers in matrix is highly anisotropic material. When such a composite is loaded at an angle to the fibers three strength parameters must be considered. The stress required to produce failure by flow parallel to fibers is σ_c given by

$$\sigma_{cu} = \sigma_f f_f + \sigma'_m (1 - f_f)$$

where σ_{cu} = ultimate tensile strength of composite

σ_f = ultimate tensile strength of fiber

σ'_m = it is the flow stress in matrix at a strain equal to fiber breaking stress.

ff = volume fraction of fibers

the shear stress required to produce failure by shear in the matrix or at the fiber matrix interface is τ_s , while σs is the tensile stress required to produce failure of the composite in a direction normal to fibers. The tensile stress to produce failure of the composite by fracture of the fibers is

$$\boldsymbol{\sigma = \sigma_c \sec^2\theta}$$

where $\boldsymbol{\sigma_c}$ = ultimate tensile strength of composite.

θ= angle between fibers and tensile axis.

If failure occurs by shear in the direction of fibers on a plane parallel to the fibers, the failure stress is given by

$$\boldsymbol{\sigma = 2\,\tau_s \operatorname{cosec}^2\theta}$$

It is seen that the strength of a unidirectional composite falls of significantly at small departures from the fiber orientation (fig. on page 27).

One of the consequences of the anisotropy of fiber composites is that they display shear coupling. This means that an axial stress produces shear strains and a shear stress produces axial strain. In an isotropic material a uniaxially applied load produces only axial and transverse normal strains. But in a fiber reinforced material in addition to these normal strains resulting from a uniaxial load there is a shear strain.

Change of temperature: - A change in temperature can alter the relative rates of the diffusion and relaxation processes in the polymer matrix. At room temperature failure is characterized by matrix cracking and good matrix-fiber adhesion. At 120°C matrix cracking becomes more pronounced and the beginning of fiber pullout can be seen as the glass transition is approached. This decrease is due to the beginning of fiber pullout failure and increased matrix cracking. As the testing temperature approaches the glass transition temperature, the response of the composite becomes increasingly matrix dominated. Differences between the thermal coefficient of expansion of the reinforcement and that of the matrix phase, together with the cure shrinkage associated with thermosetting resins can often induce stress concentrations at the interface.

Previous works done on this project:

Works done by E.P. Gellert and D.M. Turley

E.P. Gellert and D.M. Turley worked on "**sea water immersion aging of glass fiber reinforced polymer laminates for marine application"**. They have found out that:-

- The water uptake behaviour of Phenolic GRP and cast resin was very different from that of other system. Uptake mechanisms related to the interface were strongly indicated for the phenolic GRP. Supplementary uptake behaviour possibly related to osmosis at the interface was evident for the polyester and vinylester beyond about 10 days$^{1/2}$(Fig. on page 28).
- Flexural strength continued to degrade for the unloaded polyester and vinylester GRPs as water uptake continued toward saturation, where strength losses between 15 and 21% occurred. The unloaded phenolic lost 25% of initial strength at, saturation, with no further loss as immersion continued from, 200 to 800 days. Loading while ageing affected the strength of only the phenolic GRP with strength loss advancing from 25 to 36% loss from the initial strength over this period.
- Interlaminar shear strengths fell by between 12 and 21% after 485 days immersion, at which time only the phenolic was saturated, and the other GRPs were estimated to be 80–90% saturated.
- Creep was significantly higher for the immersed than for the atmospherically aged laminates where ageing had been accompanied by flexure loading at set deflections (0.2 1f)(Fig. on page 29).

Work done by G. Zaffaroni & C. Cappelletti

G. Zaffaroni & C. Cappelletti worked on "**fatigue behavior of glass-reinforced epoxy resin submitted to hot-wet aging".** They have found out that:-

- Heavy static degradation occurs especially at elevated temperatures. This is true also for 0° properties.
- Tensile fatigue properties at low loads, at least for the resin properties dominated lay-ups, show no degradation generated by moisture absorption (Fig. on page 30).

The degradation of elastic properties and the glass transition temperature (and therefore the maximum operative temperature) are easily explained by the enhanced plasticization of the epoxy resin. In testing wet quasiisotropic specimens, for example, it has been found that 90° ply damage does not clearly develop, in contrast to the dry case. As far as the mechanical fatigue is concerned, it seems that for the (645°)4s quasi-isotropic specimens considered here, the moisture absorption does not affect the behavior when the part of the curve at a high number of cycles is considered (cycles more than 10^3). Therefore, in this range of cycles one cannot expect that the fatigue curve for the wet (40%) case becomes lower with respect to the dry curve.

Work done by Dr. B.C. Ray

Dr. B.C.Ray worked on "**effects of changing seawater temperature on mechanical properties of GRP composites".** He has found out that

- The weakening effects were sensitive to loading rate
- The maximum interlaminar shear strength fell by 35% in glass/epoxy composites (in 55 and 65 weight % fibers) and by 33% in glass/polyester composites (in 60 weight % fibers) as a result of the most severe conditioning cycles (Fig. on page 31).
- The reduction in shear strength in general was less at high crosshead speeds. This may have been linked to a reduction in matrix ductility.
- It was also observed that the reduction in shear strength was dependent on the volume fraction of fibers. A reduction in ILSS values was observed for both the lowest and highest fiber volume fractions in the present experiments. This could be attributed either to matrix damage or to interfacial damage. A greater amount of matrix phase was obviously present in the laminates with low fiber volume fractions. Higher fiber content means a greater interfacial area.
- The cumulative effect of thermal shock, thermal fatigue and aqueous environment was observed to be deleterious for the mechanical properties of polymer composites. The behaviour of GRP composites in such environments was sensitive to the variations of constituent phases and also to the loading speed (Fig. on page 32).

Considering all the previous work done we can say that when GRP laminates were immersed in sea water they get degraded due to water absorbed by GRP laminates. The loading rates affect the strength of matrix and in some cases the interlaminar shear strength falls by a higher amount if loading rate is high. At elevated temperatures due to difference in thermal expansion coefficient of matrix and fibers the matrix and fiber expand at different rate resulting in delamination of fibers. This causes decrease in composite strength and in its mechanical properties.

CHAPTER 3

LITERATURE SURVEY

Literature survey

SL. NO.	Topic	Authors	Brief description of literature	Conclusion	Reference
1	Effects of changing sea water temperature on mechanical properties of GRP composites	B. C. Ray	Glass fibers were exposed to two sea water bath and then subjected to two thermal shocks (higher and lower side).	Interlaminar shear strength gets changed when composite is subjected to two different sea water baths.	Published in Polymers and Polymer Composites, 2006
2	Effect of Material Anisotropy and Curing Stresses on Interface Delamination Propagation Characteristics in Multiply Laminated FRP Composites	Brajabandhu Pradhan, and Saroja Kanta Panda,	The present study encompasses the thermoelastic effect of material anisotropy and curing stresses on interlaminar embedded elliptical delamination fracture characteristics in multiply laminated fiber-reinforced polymeric (FRP) composites.	Due to different magnitude of properties in different direction it has been found that cracking takes place in particular direction in which there is less strength. This arises due to anisotropy in material and due to curing stresses present in the system.	Journal of Engineering Materials and Technology, Vol. 128, No. 3, pp. 383–392, July 2006
3	Delamination in drilling GFRP composite	U. A. Khashaba	The influence of drilling and material variables on thrust force, torque and delamination of GFRP composites was investigated.	At minimum cutting variables the thrust force of continuous-winding, woven/epoxy and chopped composites were suddenly dropped from the maximum value to zero at the drill exit with significant push-out	August 2003

				delamination. On the other hand a gradual decrease in thrust force was observed for cross-winding composites resulting in delamination-free at drill exit.	
4	Analysis of flexural tests for transverse tensile strength characterization of unidirectional composite	T. Kevin O'Brien and Ronald Krueger	Finite element (FE) analyses were performed on 3-point and 4-point bending test configurations of glass-epoxy and carbon-epoxy Unidirectional tape beams tested at ninety degrees to the fiber direction to identify deviations from beam theory predictions.	For 3-point bend test configurations, both the linear and geometric non-linear 2D plane-strain and plane-stress analyses yielded similar results For 4-point bend test configurations, both the plane-stress and plane-strain 2D linear analysis results agreed closely with beam theory except right below the load points.	Journal of Composites, Technology & Research, Vol. 25, No.1, November 2002
5	Strain rates and temperature effect on mechanical properties of E-glass composite	Joseph T. South, Kenneth L. Reifsnider, and Scott W. Case	This tells about the change in mechanical properties of E-glass composite if strain rate and temperature is changed	The Monkmann-Grant approach is a viable means of predicting the time to failure for a polymer matrix composite.	Journal of Composites Technology & Research, Vol. 23, No. 3, July 2001

6	Fatigue behavior of Glass Reinforced epoxy resin submitted to hot wet ageing.	Giorgio Zaffaroni1 and Claudio Cappelletti2	To assess the effect of hot-wet aging on the properties of a glass-reinforced epoxy resin, three kinds of specimens were subjected to static and dynamic (fatigue) tests, in both dry and moisture-saturated conditions	1. Heavy static degradation occurs especially at elevated temperatures. This is true also for 0° properties. 2. Tensile fatigue properties at low loads, at least for the resin properties dominated lay-ups, show no degradation generated by moisture absorption.	Journal of Composites Technology & Research, Vol. 22, No. 4, October 2000
7	Effect of moisture on mechanical properties of glass fiber reinforced vinylester resin composites	Rita Roy, B.K. Sarkar and N.R. Bose	GRP incorporating various amount of fibers were characterized for their mechanical properties both as prepared and after treatment with boiling water for 2,4,6,8,24 hrs.	The properties were inferior when treated with boiling water for longer hours.	Bull. Mater. Sci., Vol 24, No. 1, Feburary 2001
8	Introduction to Composite material	David Roylance	It tells about properties of composite.	Composites have various pro like stiffness and strength to ratio.	March 2000
9	Volume fraction effects on interfacial adhesion strength of glass-fiber-reinforced polymer	W. Gu, H. F. Wu, S. L. Kampe and G. -Q. Lu	A simple optical system was contributed for measuring the damping factor of uniaxial fiber-reinforced polymer composites in the shape of cantilever beams. The	The interfacial damping factor is proportional to the volume fraction of fibers. As the volume fraction of fibers in the composite increases, more fiber–matrix interfacial	January 2000

	composites		interfacial damping factors in glass-fiber-reinforced epoxy resin composites were correlated with transverse tensile strength, which is a qualitative measurement of adhesion at the fiber–matrix interface.	area is created, and more energy can be dissipated by the fiber–matrix interface. The obtained interfacial damping factors were correlated with transverse tensile strength	
10	Sea water immersion ageing of GFRP laminates for marine application	E.P. Gellert & D.M. Turley	This says about the degradation of composite in sea water.	Flexural strength continued to degrade for the unloaded polyester and vinylester GRPs as water uptake continued toward saturation, where strength losses between 15 and 21% occurred	Composites Part A 30 (1999)
11	Shear strength of polymers and fibers composites Carbon/epoxy	K. Liu and M.R. Piggott	Three different curing agents were used so that the matrices were resins with different glass transition temperature	Fiber architecture play a dominant role in the composite shear strength.	Composites 26(1995)
12	Freezing and thermal spikes effect on interlaminar shear strength hygrothermal glass fiber epoxy composite	B.C. Ray, A. Biswas, P.K. Sinha	To study the effect of moisture on interlaminar shear strength of glass fiber epoxy resin	When the absorbed moisture becomes frozen it shows detrimental effect on interlaminar shear strength.	Polymer and Polymer Composites 1995

13	Rate/frequency-dependent behavior of Fiber glass/epoxy laminates in tensile and cyclic loading	D. Kujawski and F. Ellyin	The time (rate and frequency) effect on the stress-strain response, creep, relaxation and cyclic behaviour of an angle-ply Fibreglass/epoxy laminate. The angle-ply +45 ° lay-up was chosen because it exhibits significant inelastic matrix dominated behaviour.	The viscous effects are significant at room temperature for both monotonic and cyclic loadings. The loading frequency has a significant effect on the Cyclic creep rate, which depends on the stress level.	Composites 26(1995)
14	Shear strength of polymers and fiber composites: Thermoplastics and thermoset polymer	K. Liu and M.R. Piggott	The shear strength of eight thermoplastic and three DGEBA based epoxies in sheet form have been tested by the punch and losipescu tests.	Ratio of compressive yield strength to shear yield strength was found out to be varied from 1.5-2.4.	Composites 26(1995)
15	Hygrothermal effects on mechanical behavior of FRP composite	B.C.Ray, A. Biswas, P.K. Sinha	To show that hygrothermal effect is similar to temperature change effect in composite.	Hygrothermal diffusion in polymeric composite is mostly Fickian type but can be non Fickian type in some glass epoxy resin composite.	Metals Materials and Processes, 1991, Vol 3

CHAPTER 4

EXPERIMENTAL PROCEDURE

EXPERIMENTAL PROCEDURE

An unmodified epoxy resin based on bisphenol-A (Ciba-Geigy, India) were used with woven roving E-glass fibres (Saint-Gobain) to fabricate composite laminates by hand lay-up. The laminates were fabricated with several glass layers to acquire the thickness required for ASTM D 2344-84. The laminates were cut to the required dimensions for the 3-point SBS test using a diamond cutter. The laminates were cut at specified angles in order to bring the directionality in the specimen. The angles were ranging from 0^o to 90^o at a difference of 15^o each. The SBS test specimens were kept in oven at 50^o Celsius and were kept in desiccators for several days until their weights stabilised. The samples were immersed in a seawater bath in an oven at 60 C for period ranging from 10 to 80 hours with a difference of 10 hours. The weathered specimens were wrapped in aluminium foil to minimise further environmental interactions before mechanical testing. Three-point bend tests were performed within the shortest possible time after conditioning. The off-times were kept the same for all the aged specimens to eliminate/minimise the possibility of a recovery process by relaxation at ambient conditions. The aged specimens were tested in a 3-point flexural mode to determine the ILSS. The tests were conducted at room temperature using an Instron machine. The experiments were carried out in accordance with ASTM D 2344-84 at crosshead speeds of 2 mm/min for each stage of cyclic treatment of the specimens. About 10 samples were tested at each point of the conditioning cycle to calculate a reasonable standard deviation limit. The data that were within the acceptable limit were accepted, and any others were rejected. The ILSS value was determined by the equation:

$$ILSS = 0.75p_b /bd$$

Where p_b was the breaking load, b the width and d the thickness of the specimens.

The results of the tests will be presented in tabular form and in graphical form.

A comparison between sea water aged sample and atmospheric cured sample would be made on the basis of nature of failure, nature of interfaces on investigation of data obtained from tests. SEM testing of the fractured samples was also done in order to know the cause of failure.

CHAPTER 5

RESULTS AND DISCUSSION

RESULT & DISCUSSION

1. MOISTURE ABSORPTION:-

After preparation of the samples they were treated with sea water for 80 hours at a temperature of 60 degrees. From this sea water treatment we were able to know the water absorption rate as a function of time as well as fiber orientation. The results are given in graphical form.

FOR ATMOSPHERE AGED SAMPLE

SERIAL NO.	TIME	INITIAL WEIGHT (gms.)	FINAL WEIGHT (gms.)	MOISTURE ABSORBED %
1.	0	3.83	3.83	0
2.	0	3.84	3.84	0
3.	15	3.43	3.43	0
4.	15	3.43	3.43	0
5.	30	3.13	3.13	0
6.	30	3.13	3.13	0
7.	45	3.365	3.365	0
8.	45	3.364	3.364	0
9.	60	3.37	3.37	0
10.	60	3.4	3.4	0
11.	75	3.465	3.465	0
12.	75	3.44	3.44	0
13.	90	3.71	3.71	0
14.	90	3.68	3.68	0

TABLE 5.1

FOR ZERO DEGREE SAMPLE

SERIAL	TIME	INTIAL Wt. gms	FINAL WT. Gms	MOISTURE ABSORBED %
1.	10	3.83	3.85	0.5
2.	20	3.84	3.87	0.78
3.	30	3.86	3.9	1.03
4.	40	3.55	3.6	1.4
5.	50	3.76	3.83	1.86
6.	60	3.71	3.78	1.86
7.	70	3.81	3.88	1.86
8.	80	3.65	3.72	1.86

TABLE 5.2

FOR 15 DEGREE SAMPLE

SERIAL	TIME	INTIAL Wt. gms	FINAL WT. Gms	MOISTURE ABSORBED %
1.	10	3.43	3.45	.58
2.	20	3.735	4.035	.80
3.	30	3.345	3.745	1.03
4.	40	3.66	3.71	1.4
5.	50	3.35	3.41	1.8
6.	60	3.64	3.71	1.86
7.	70	3.5	3.57	1.86
8.	80	3.79	3.86	1.86

TABLE 5.3

FOR 30 DEGREE SAMPLE

SERIAL	TIME	INTIAL Wt. gms	FINAL WT. Gms	MOISTURE ABSORBED %
1.	10	3.13	3.14	.32
2.	20	3.07	3.1	.8
3.	30	3.34	3.38	1.1
4.	40	3.66	3.71	1.4
5.	50	3.27	3.34	1.84
6.	60	3.63	3.7	1.86
7.	70	3.24	3.31	1.86
8.	80	3.3	3.37	1.86

TABLE 5.4

FOR 45 DEGREE SAMPLE

SERIAL	TIME	INTIAL Wt. gms	FINAL WT. gms	MOISTURE ABSORBED %
1.	10	3.37	3.39	.59
2.	20	3.66	3.69	.81
3.	30	3.56	3.6	1.03
4.	40	3.67	3.72	1.4
5.	50	3.49	3.55	1.8
6.	60	3.43	3.5	1.86
7.	70	3.56	3.63	1.86
8.	80	3.51	3.58	1.86

TABLE 5.5

FOR 60 DEGREE SAMPLES

SERIAL	TIME	INTIAL Wt. gms	FINAL Wt. gms	MOISTURE ABSORBED %
1.	10	3.36	3.38	.59
2.	20	3.41	3.44	.8
3.	30	3.29	3.33	1.03
4.	40	3.38	3.43	1.4
5.	50	3.33	3.40	1.86
6.	60	3.34	3.41	1.86
7.	70	3.21	3.28	1.86
8.	80	3.31	3.38	1.86

TABLE 5.6

FOR 75 DEGREE SAMPLE

SERIAL	TIME	INTIAL Wt. gms	FINAL WT. gms	MOISTURE ABSORBED %
1.	10	3.46	3.48	.58
2.	20	3.36	3.39	.8
3.	30	3.69	3.73	1.04
4.	40	3.27	3.32	1.4
5.	50	3.49	3.55	1.8
6.	60	3.35	3.42	1.86
7.	70	3.41	3.48	1.86
8.	80	3.58	3.65	1.86

TABLE 5.7

FOR 90 DEGREE SAMPLE

SERIAL	TIME	INTIAL Wt. gms	FINAL WT. gms	MOISTURE ABSORBED %
1.	10	3.71	3.73	.53
2.	20	3.63	3.66	.82
3.	30	3.57	3.61	1.1
4.	40	3.49	3.54	1.43
5.	50	3.59	3.65	1.8
6.	60	3.7	3.77	1.86
7.	70	3.93	4.00	1.86
8.	80	3.46	3.53	1.86

TABLE 5.8

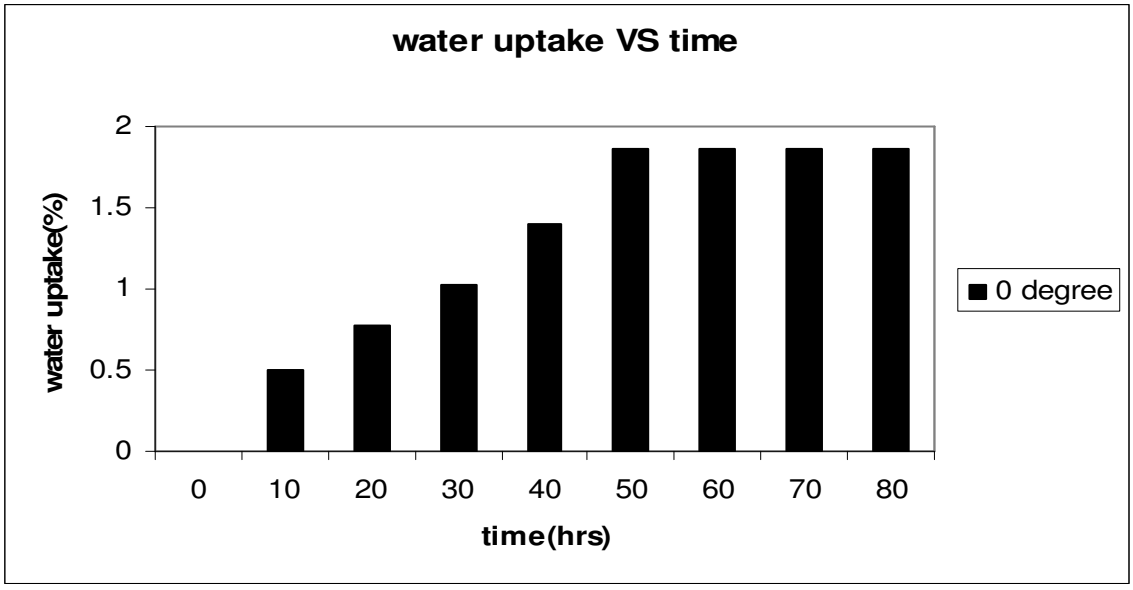

FIG. 5.1

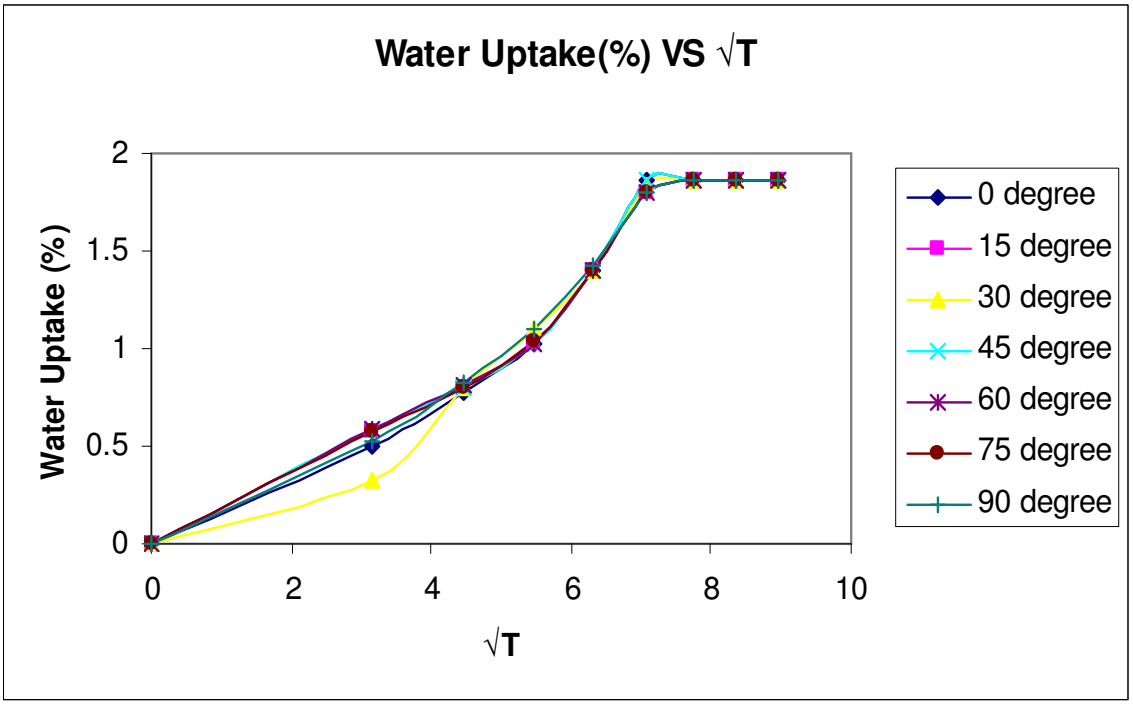

FIG 5.2

From the first graphs we can see that the sea water intake goes on increasing with time upto some hours and then become constant as the saturation limit is reached. Furthermore from the second graph we can see that the water intake does not depend on the orientation of the fibers. This is so because the absorption limit of water does not depend upon the orientation of fibres. It only depends upon the temperature and time of holding the specimen in the sea water. So we can say that water intake remains constant with respect to fiber orientation.

2. 3-POINT BEND TEST:-

After sea water treatment we went for 3-point bend test in an INSTRON 1195 machine.

Then the results were plotted graphically as shown below.

Serial No.	Degree	Normal ILSS	10 hrs. ILSS	20 hrs. ILSS	30 hrs. ILSS	40 hrs. ILSS	50 hrs ILSS	60 hrs. ILSS	70 hrs. ILSS	80 hrs. ILSS
1.	0	0.026074	0.025368	.02401	0.023594	0.0226	0.02175	0.02081	0.0196	0.0184
2.	0	0.027593	0.026251	0.025618	0.024539	0.02399	0.022701	0.02152	0.02086	0.019453
3.	15	0.022242	0.0211	0.020777	0.019472	0.01884	0.017219	0.0163483	0.015538	0.01472
4.	15	0.02485	0.023555	0.022537	-	0.018817	0.018514	0.01798	0.016974	0.014434
5.	30	0.017554	0.015293	0.014564	0.01346	0.01286	0.012568	0.01151	0.010409	0.00989
6.	30	0.015427	0.014288	0.013861	0.012974	0.012438	0.011676	0.01105	0.01062	0.010205
7.	45	0.013932	0.013052	0.01281	0.012551	0.011924	0.011251	0.010463	0.00955	0.009222
8.	45	0.015126	0.01453	0.013519	-	0.012892	0.01188	0.0112598	0.0108358	0.0100
9.	60	0.016735	0.016236	0.015883	0.013036	0.012756	0.0121211	0.011848	0.01052	0.010
10.	60	0.016728	0.015364	0.014866	0.013674	0.01247	0.012	0.011387	0.010643	0.010
11.	75	0.023739	0.021478	0.020432	0.016282	0.01583	0.014804	0.013954	0.01256	0.01183
12.	75	0.021613	0.019183	0.018024	0.016593	0.015502	0.014734	0.013858	0.012103	0.011132
13.	90	0.025674	0.02402	0.02303	0.022571	0.021501	0.020786	0.02029	0.01954	0.01882
14.	90	0.028124	0.027289	0.026032	0.024194	0.023467	0.022657	0.021606	0.02026	0.01925

TABLE 5.9

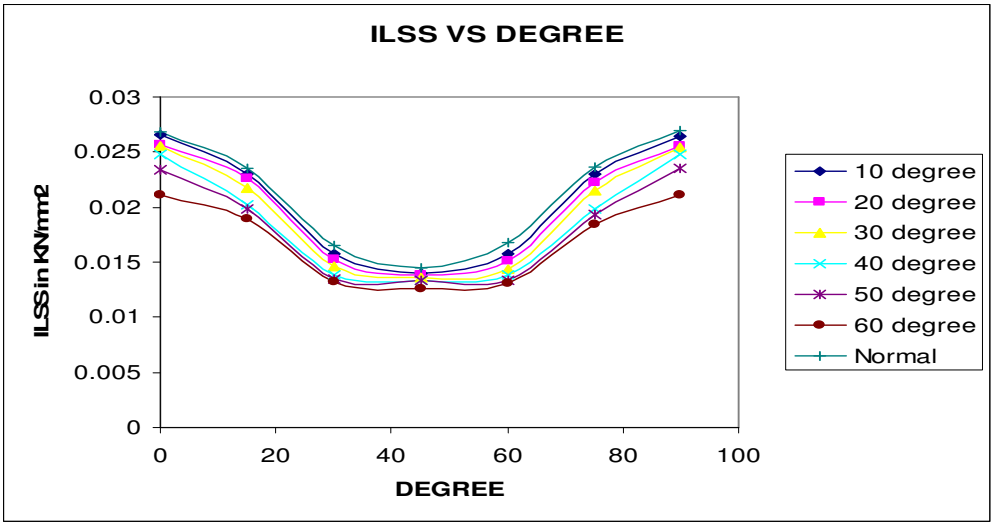

FIG. 5.3

From the curve we can conclude that as the angle of fiber orientation increases the ILSS value goes on decreasing. But since we have taken woven fiber so after 45 degree the ILSS value again starts increasing. This is so happening because the fibers are perpendicular to each other and hence they make equal angles Furthermore if the fibers were aligned in single direction only then the ILSS value might be decreasing for increasing value of angles. We can also interpret that the ILSS value goes on decreasing as the time for sea water treatment goes on increasing. This is so happening because sea water which gets absorbed starts diffusing into the matrix and delamination of matrix occurs. Furthermore the ions present in sea water also deteriorate the matrix.

3. SEM ANALYSIS:-

After 3-point bend test we went for SEM analysis of the fractured surface of some of the samples. Here we can see that as the time increases debonding starts occurring in between the fibers and the matrix. Furthermore after the application of load the fibers also start breaking in aid to debonding. Scanning electron micrographs show extensive matrix cracking and interfacial cracking in the conditioned specimens. The presence of these cracks can often lead to interfacial debonding, matrix fracture and post-debonding friction. Fracture behavior in GRP composites is seldom conclusive because of their micro structural in homogeneity. Thermal shock and thermal fatigue during ageing can induce matrix and interfacial cracking in glass/epoxy and glass/polyester composites. Cracks and debonded areas, nucleated by high residual stresses as a result of the changing aqueous environment, can easily propagate at the weaker interface. The continuous fall in ILSS values for all cases can be attributed here to matrix cracking and/or interfacial debonding. The differential change in the condition of constituent phases (fibre, matrix resin and interphase) of fibrous polymer composites in such harsh and hostile environments can result in a significant mismatch among constituents and this eventually leads to the evolution of localized stress and strain fields in composites. The situations could easily result in the nucleation of delaminating micro cracks in the composites. The cracks would be expected to propagate preferentially along the fibre/matrix and laminar interfaces.

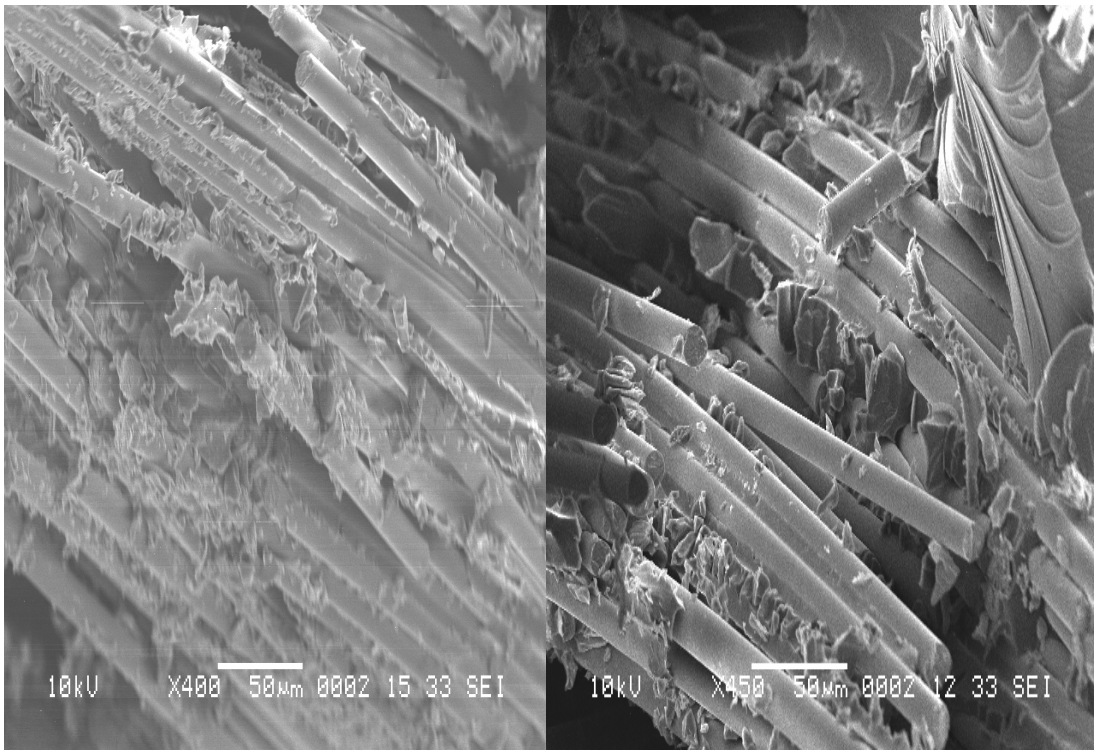

FIG. 5.4 SEM Image Of samples (Dry & Wet for 40 hrs.) at 45 degree

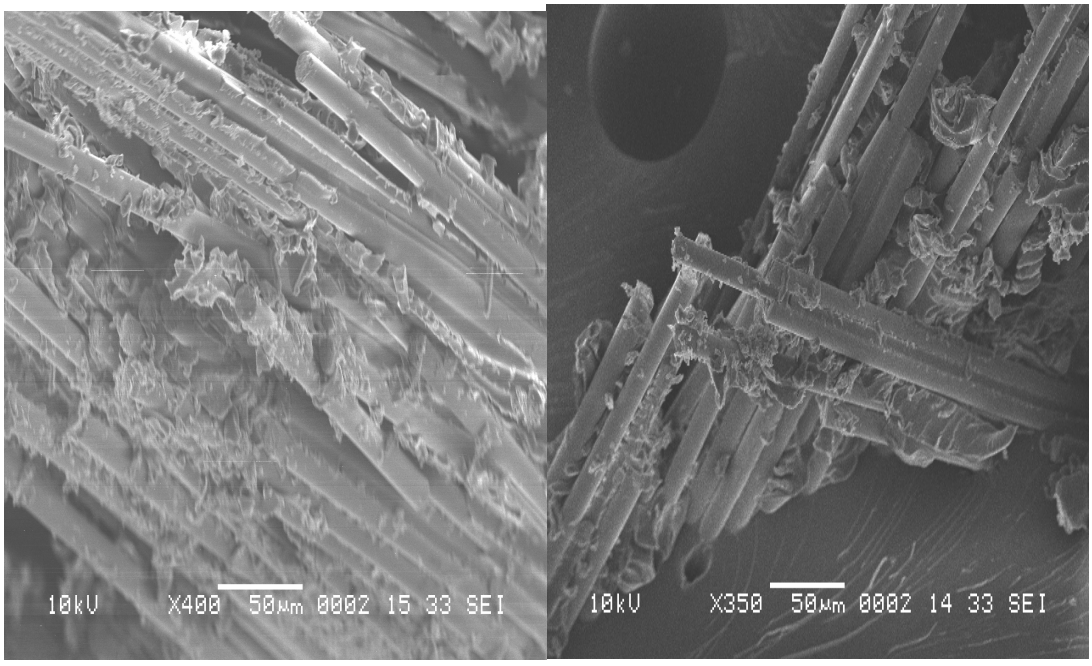

FIG. 5.5 SEM Image of Samples (Dry &wet for 80 hrs) at 45 degree

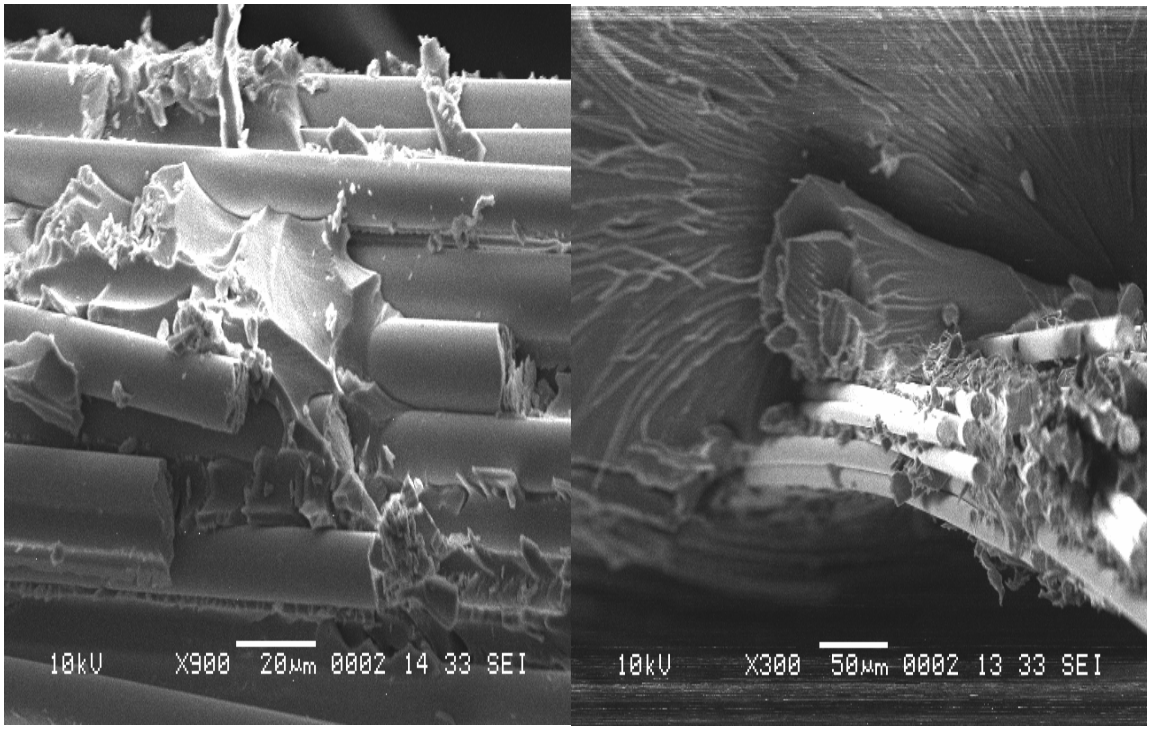

FIG. 5.6 SEM Image of samples (Dry & wet for 40 hrs) at 75 degrees

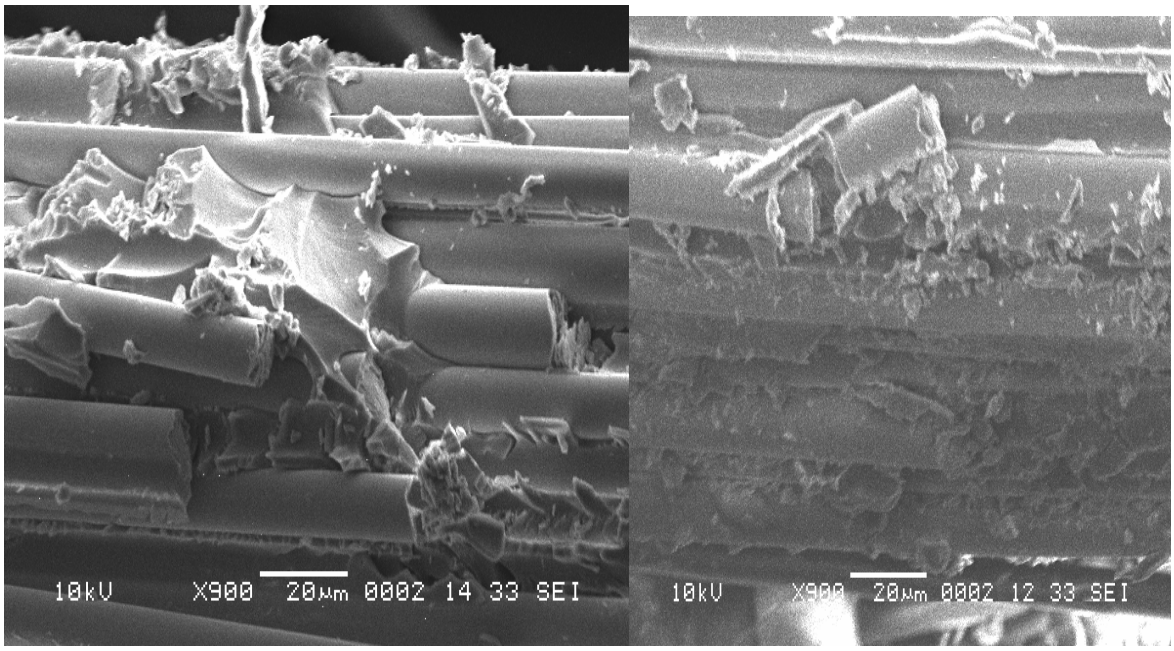

FIG. 5.7 SEM Image of samples (dry & wet for 80 hrs) at 75 degree

CHAPTER 6

CONCLUSION

Conclusion

The effect of changing seawater temperature during immersion ageing of glass/epoxy and glass/polyester composites on ILSS has been shown. A reduction in ILSS values was observed for both the lowest and highest fibre volume fractions in the present experiments. This could be attributed either to matrix damage or to interfacial damage. A greater amount of matrix phase was obviously present in the laminates with low fibre volume fractions. Higher fibre content means a greater interfacial area. Moreover the effect was more pronounced when the orientation of fiber changes from 0 to 45 degree. The cumulative effect of thermal shock, thermal fatigue and aqueous environment was observed to be deleterious for the mechanical properties of polymer composites. Hence we conclude that sea water intake increases with time of exposure, ILSS value goes on decreasing with time of exposure to the sea water treatment, ILSS value first decreases with directionality and then increases due to woven fiber taken in this case and lastly sea water has very detrimental effect on both fiber and matrix.

CHAPTER 6

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